3 Methodology

The reason for undertaking this study was to examine and then show how Japan can supply itself exclusively with technologies that utilise renewable energy sources. The study looked at the full range of renewable energy sources available, including supply solely from regional (Japanese) sources. In addition, it was important to formulate and test a plausible model for an energy demand based on efficient technologies.

An energy system consists of inputs (such as oil, coal and gas, nuclear power, hydropower, photovoltaic, wind power etc) and outputs (such as energy in the form of electricity, heat and fuels), which vary over time. Energy demand is that part of the system, which consumes energy in the form of electricity, heat and fuels provided by the supply side of the system to make available services such as heating, lighting, transportation, communication and power for appliances.

In order to develop a sustainable system, demand and supply must be researched. In order to accurately analyse energy consumption, a demand model was built to reflect the actual demand in Japan in detail by identifying all areas and sectors where energy was consumed. These sectors included industry, commercial, residential and transport. It was then possible to detect all potential reductions in each sector.

In order for the study to remain conservative, it was considered an important precondition that the project team researched the possibilities of reducing demand without making any changes to the level of industrial production and without involving any reductions in the standard of living or making lifestyle alterations. This established that a reduction in demand is theoretically possible using today's best available technologies (BAT) and can be implemented without having to stipulate a restructuring of society or industry. For the same reason, other factors that would have helped to reduce demand, such as increases in resource productivity or moves toward sufficiency were also not included.

The population decline scenarios consider a reduction of approximately 27 million. This demographic trend, predicted by the Japanese[12] themselves will see a generally more elderly population totalling 100 million by the year 2050. In order to address this in the "Energy-Rich Japan" scenarios, a straightforward decline was adopted for the subsequent demand reduction. In reality a declining and more elderly population would have a far more complex effect on demand. Smaller households generally use more energy per capita and a smaller workforce would impact on production levels[13]. Energy use per capita would decline in some areas and increase in certain oth-

12. National Institute of Population and Social Security Research (2001).
13. Increasing energy use over time, i.e. future trends to smaller households, while an increasing issue in Japan, is not addressed in this report.

ers. There is no clear existing connection that can be drawn upon in order to make a prediction, so for the sake of simplicity a linear decline was adopted.

Japanese energy demand data was taken from the year 1999, which was chosen as a reference year for the determination of the Energy-Rich Japan (ERJ) Demand Model. Research was conducted using both “bottom-up” and “top-down” approaches. In the bottom-up approach, research into energy saving measures was applied, such as identifying and implementing the latest best available technologies and environmental designs in all sectors of demand, such as efficient vehicles, and then calculating the decrease in demand. With the top-down approach, European studies conducted in the area of energy efficiency and environmental designs were adopted in all sectors in Japan. The advanced level of technology in Japan meant that European efficiency potentials had to be lowered by varying percentages according to the sector. This was supported by comparing the production of specific goods, such as steel production statistics in Europe and Japan. For example, the energy required to produce a tonne of steel in Japan was compared to the energy required for producing a ton of steel in Europe. Taken across all areas of industry, commercial, residential and transport, this provided a clear indication of the comparative efficiency potentials and therefore the difference in potentials required for the study. These potentials were then applied to the ERJ Model.

It must be noted that increases in efficiency must not be considered as “income” (in energy terms) and then lead to increased consumption or output i.e. energy “saved” by efficiency must not then be considered available for “spending” elsewhere. This is commonly referred to as the “rebound effect” and must be avoided if energy consumption is to be reduced.

The renewable sources in the supply model required to meet this reduced demand were then determined. To this end, a supply model was developed to cover electricity, heat and fuels. The ERJ Supply Model incorporated a wide variety of the latest renewable energy technologies such as electricity from photovoltaic cells, wind and hydropower, heat from thermal solar panels and geothermal sources, hydrogen for fuels and energy storage from diverse renewable sources. The cogeneration of heat and power was also utilised.

At the time of preparing the study there are significant uncertainties regarding the potential volume of sustainable produced domestic biomass in Japan. For this reason, details regarding the value of biomass in Japan were not incorporated in this study. Nevertheless, biomass will make an important contribution to a future energy supply.

The ERJ Supply Model was designed to supply energy in the form of electricity, heat and fuels at anytime throughout the year. To achieve this, fluctuating sources, such as wind and solar power were combined with adjustable suppliers such as geothermal or combined heat and power, to provide a reliable supply of energy throughout the year. Surpluses in the electrical supply system were converted into hydrogen that was used as a fuel for different types of factories or processes.

Energy is supplied in the form of electricity, heat or fuels. Heat and fuels have the advantage that they can be stored for later use and can be easily transported. So it is not necessary to consume heat and fuels immediately or in the place they were produced. Heat can be stored in thermal reservoirs and distributed via district heating networks. Both heat and fuels dissipate with time, which sets a limit to storage time and distribution distance. As for fuels from biomass or hydrogen, there is no limitation in storage time or in transport (depending on the fuel type - solid, liquid or gaseous) but storage losses must be considered.

The situation is completely different with electricity. The necessity of producing enough electricity, on demand and on time, makes this type of energy the most critical component in an energy supply system. While electrical transport via the public grid is quite unproblematic, storing electricity directly on a large scale is material- and cost- intensive. Indirect storage is used in the study by utilising hydrogen and pumped storage.

An energy supply system which is based solely on renewable sources increases the focus on timely energy provision due to the fluctuating nature of some renewable energy sources, such as solar and wind. Including such fluctuating sources into the public electricity supply means that the proportion of electricity produced by those sources might decrease suddenly. Of course electricity production from fluctuating sources can be estimated by weather forecasting but a portion of uncertainty still remains (particularly in a world starting to show the effects of climate change). Fortunately, there are other renewable technologies with the ability to deliver energy on demand; hydropower and geothermal power plants give direct access to renewable sources, cogeneration and other energy sources can use fuel from renewable sources (e.g. hydrogen or biomass).

The challenge in designing a reliable fully renewable energy system was to find a combination of technologies where the pros of some types balanced out the cons of the others. A reserve capacity is necessary as a backup for fluctuating sources, especially in the electrical system. The size of the reserve capacity required can be minimised by designing a combination of renewable technologies where fluctuations in production match a varying demand, so that any fluctuations in supply never lead to electrical production that cannot meet the demand.

The focus in designing the ERJ Supply Models was therefore on the electrical subsystem, as this is the most (time) critical component of supply. The simulation of the electrical energy supply using SimREN, a specially designed software program, was used to optimise the system by first determining the amount and locations of energy sources and performing a simulation run.

For the study Japan was divided into twelve geographical regions[14], which were able to exchange energy supply with each other. Weather information from 153 weather sub-regions across Japan, including wind speeds and temperatures ensured that Japanese weather was realistically reflected in the simulation. In addition, 66 of these weather stations provided solar radiation data. River level data from 1999 was also available for the estimation of the existing hydropower capacity. This enabled a realistic reflection of the energy potential of fluctuating energy sources such as windmills. A resolution of fifteen minutes also made sure that changes in weather conditions and hence supply were incorporated in the simulation, guaranteeing a reliable energy supply throughout the year. Intelligent control of differing renewable energy sources was performed using an energy manager.

Improvements were implemented in the supply model in order to optimise the system, such as increasing the number of windmills in one region, or altering the mix of renewables, so that the goal of using regional Japanese sources to supply electricity domestic without any loss of integrity in the system was achieved. The heat and fuels supplying system was then designed.

The result was Scenario One, which is described in detail in this report. This system is capable of reliably delivering electricity, heat and fuels in the demand and supply. Then a number of variations on this scenario were calculated to show different energy mixes including a version which supplies Japan completely with energy from domestic sources. A variation on these three scenarios was calculated incorporating a predicted decline in the Japanese population from 127 million in 1999 to 100 million by the year 2050.

Three prominent scientists from Japan and four from Europe were consulted as external reviewers of the draft of the report. Their comments were taken into account as much as possible in order to produce this final version.

14. The remote islands of Okinawa were not considered as a region, but were partially included into Kyushu South.